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A quantitative study of the factors influencing the weight of the bean seed—II. Correlation between number of pods per plant and seed weight

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(WITH FOUR TEXT FIGURES)

I. INTRODUCTORY REMARKS

This study, like the one which preceded it,* presents a portion of the results of an attempt to express in quantitative terms the influence of the various differentiable factors to which the weight of the bean seed is due.

Such an investigation has a three-fold significance: (*a*) it has the biological interest common to studies in developmental mechanics; (*b*) it forms a part of the system of physiological data on seed production which can never be too detailed or precise as a foundation for economic science; (*c*) it pertains to a character which through the theories of Johannsen and his followers has assumed a prominent place in genetic literature.

In the first paper I considered the correlation between the characteristics of the pod (number of ovules laid down, number of seeds matured, and position of seed in the pod) and seed weight. In this place I propose to deal with the problem of the relationship between the size of the plant, as measured by the number of fertile pods produced, and seed weight. These constants will be compared with these showing the relationship between the number of pods per plant and pod characteristics, already published.

II. MATERIALS AND METHODS

The materials upon which the present discussion are based comprise 78,975 individually weighed seeds, derived from 15,897 plants, belonging to 27 experimental cultures, representing 5 varieties. These cultures were made under a wide range of environmental conditions. They are here designated by the key letters employed in other publications. It is, therefore, unnecessary to burden this paper with information which the reader who cares to do so may obtain elsewhere.*

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* Harris, J. Arthur. A quantitative study of the factors influencing the weight of the bean seed. I. Intra-ovarial correlations. Beih. Bot. Centralbl. 31^1: 1–12. *pl. 1–4.* 1913. See also: The influence of position in the pod upon the weight of the bean seed. Amer. Nat. **49**: 44–47. *f. 1–4.* 1913.

The biometric methods employed in the analysis of the data should now be familiar in a general way to all serious biological workers.†

III. PRESENTATION AND DISCUSSION OF DATA

The physical constants for the unweighted frequency distributions of both number of pods per plant and weight of seed have been given elsewhere.‡

The weighted frequency constants have little independent biological interest. We may, therefore, limit our attention to the degree of interdependence between the two variables.

The correlation coefficients for number of pods and seed weight with their probable errors and their ratios to their probable errors appear in TABLE I.

The regression straight line equations giving the numerical equivalents of

$$w = \left(\bar{w} - r_{pw}\frac{\sigma_w}{\sigma_p}\bar{p}\right) + r_{pw}\frac{\sigma_w}{\sigma_p}p,$$

where the bars denote means and the sigmas represent the standard deviations of the characters indicated by the subscripts are given in TABLE II. These show the absolute change in seed weight associated with unit change in number of pods per plant. If the regression straight lines and the empirical mean seed weights for plants with various numbers of pods for a number of series be

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* See a bibliography in Amer. Jour. Bot. 1: 410–411. 1915.

† Number of pods per plant is an integral variate which has been treated without grouping. Seed weight has been dealt with in classes of 0.025 gram range, e.g. 0.175–0.200, 0.200–0.225, 0.225–0.250. Sheppards' correction was applied to the second moment for seed weight but not to that for number of pods per plant. Number of pods per plant was of course weighted with number of seeds weighed per plant.

‡ These are sometimes based upon slightly different numbers than these here employed, but the constants are sensibly the same.

TABLE I

Series	Number of Plants	Number of Seeds Weighed	Correlation Fods and Weight	r/E_r
L	185	2861	.157 ±.012	13.08
LL	1141	3947	.074 ±.011	6.73
GG	747	8364	.055 ±.007	7.86
GGH	583	2828	.173 ±.012	14.42
GGH_2	499	1284	.081 ±.019	4.26
GGHH	396	1329	.039 ±.019	2.05
GGD	514	2140	.150 ±.014	10.71
GGD_2	449	1419	.240 ±.017	14.12
GGDD	342	1093	.193 ±.020	9.65
H	160	5778	.145 ±.009	16.11
HH	1484	7325	.191 ±.008	23.87
HHH	1271	5601	.264 ±.008	33.00
HD	1416	6630	.303 ±.008	37.87
HDD	1204	5029	.171 ±.009	19.00
D	445	2362	.031 ±.014	2.21
DD	513	2362	.339 ±.012	28.25
DDD	459	1946	.077 ±.015	5.13
DH	670	3222	.221 ±.011	20.09
DHH	565	2433	.307 ±.012	25.58
USH	361	1164	.154 ±.019	8.11
USHH	224	530	.108 ±.029	3.73
USD	312	1002	.282 ±.020	14.10
USDD	237	789	.210 ±.023	9.13
FSH	476	2117	.005 ±.015	.33
FSHH	429	1788	.053 ±.016	3.31
FSD	428	1989	.205 ±.015	13.66
FSDD	387	1643	.069 ±.017	4.06

expressed graphically on the same diagram, as in FIGS. 1 and 2,* the results seem very irregular indeed. This lack of uniformity appears in both the varying slope of the lines and in the scatter of the observed means about these lines.

The variation in the slope of the lines must be considered in relation to the great diversity in environmental conditions under which the plants were grown.

The slope of the line is determined solely by the magnitude of the absolute variation constants for seed weight and number of pods per plant and the correlation between them. The standard deviation of seed weight is relatively little influenced by the differences in environmental conditions obtaining between the cultures here considered. The standard deviation of number of pods per plant varies greatly from experiment to experiment. Thus with the same degree of correlation, the actual rate of change in seed

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* In order to accommodate as large a series as possible of figures on the same diagram the marginal scales have been given no numerical values. The numbers of pods and the end points of the lines drawn are given in the table.

TABLE II

Series	Regression Equation	End Points of Line
L	$W = .3522 + .0023\ P$	1 = .354, 31 = .422
LL	$W = .3291 + .0012\ P$	1 = .330, 27 = .360
GG	$W = .4167 + .0012\ P$	1 = .418, 26 = .447
GGH	$W = .4298 + .0027\ P$	1 = .433, 33 = .543
GGH_2	$W = .4427 + .0022\ P$	1 = .445, 17 = .479
GGHH	$W = .4409 + .0010\ P$	1 = .442, 15 = .456
GGD	$W = .3385 + .0079\ P$	1 = .347, 8 = .402
GGD_2	$W = .3609 + .0128\ P$	1 = .374, 7 = .451
GGDD	$W = .3670 + .0111\ P$	1 = .378, 9 = .456
H	$W = .2127 + .0007\ P$	1 = .214, 46 = .246
HH	$W = .2184 + .0008\ P$	1 = .219, 67 = .271
HHH	$W = .1825 + .0017\ P$	1 = .184, 34 = .241
HD	$W = .1772 + .0058\ P$	1 = .183, 14 = .258
HDD	$W = .2102 + .0027\ P$	1 = .213, 16 = .253
D	$W = .1723 + .0008\ P$	1 = .173, 9 = .180
DD	$W = .1757 + .0065\ P$	1 = .182, 14 = .266
DDD	$W = .1976 + .0014\ P$	1 = .199, 13 = .216
DH	$W = .1961 + .0009\ P$	1 = .197, 50 = .239
DHH	$W = .1797 + .0020\ P$	1 = .182, 27 = .232
USH	$W = .3182 + .0017\ P$	1 = .320, 39 = .385
USHH	$W = .3018 + .0019\ P$	1 = .305, 15 = .331
USD	$W = .2243 + .0108\ P$	1 = .235, 7 = .300
USDD	$W = .2806 + .0049\ P$	1 = .286, 16 = .358
FSH	$W = .2001 + .0000\ P$	1 = .200, 50 = .201
FSHH	$W = .1645 + .0003\ P$	1 = .165, 34 = .175
FSD	$W = .1501 + .0032\ P$	1 = .153, 10 = .182
FSDD	$W = .1632 + .0012\ P$	1 = .164, 14 = .179

W = Weight in grams, P = Pods per plant. End points of lines give calculated mean seed weight in grams for number of pods indicated.

weight will vary widely because of differences in the variability of number of pods per plant.

The irregularity of the means of seed weight for plants with different numbers of pods is attributable to several factors. Note the following:

Taken as a whole the correlations are of a very low order. In such cases the empirical means must be expected to deviate considerably from the theoretical means as predicted from the regression formula unless the number of observations be very large indeed.

Number of pods per plant is an exceedingly variable character. In consequence, the means for seed weight must, in experiments made under favorable conditions, be based upon a relatively small number of seeds, even in series in which the total number of seeds weighed is very large. It is impossible, if all series are to be treated alike, to increase the number of seeds upon which means

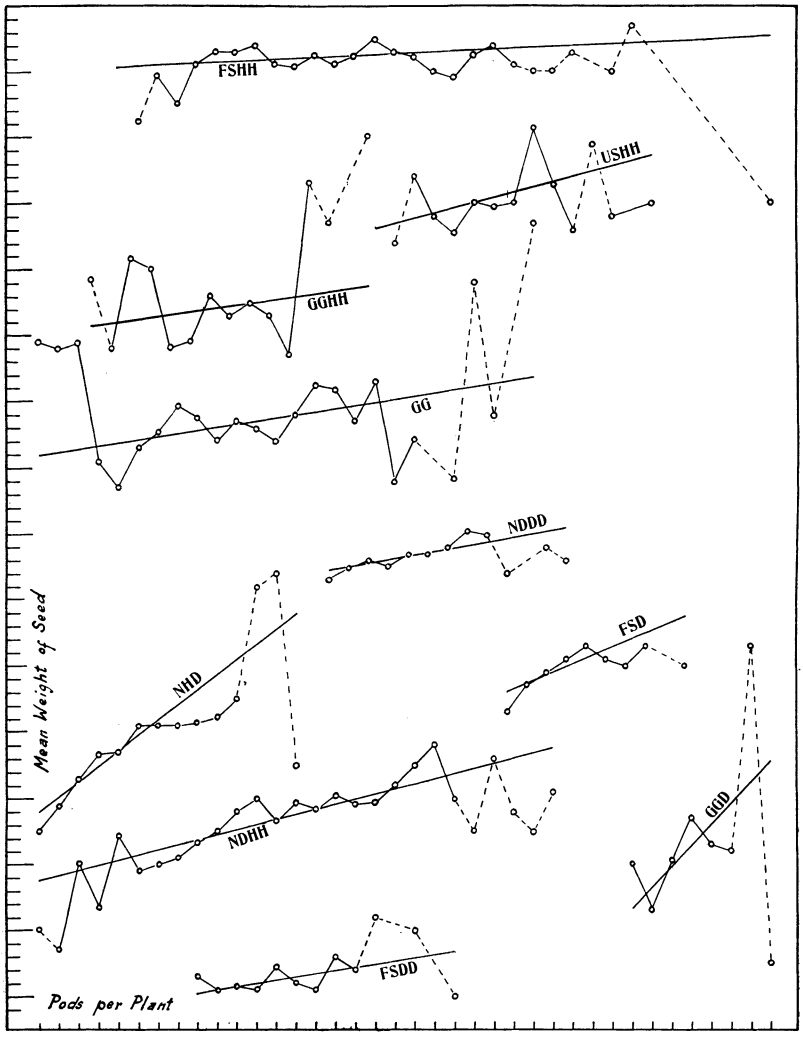

FIG. 1. Regression straight lines showing change in seed weight associated with variation in number of pods per plant.

are based by clubbing together plants with similar numbers of pods, since in many of the experiments the range of variation is too narrow to permit of such combination.

Finally, it is to be noted that in general about five seeds per plant have been weighed. When the number of plants with a

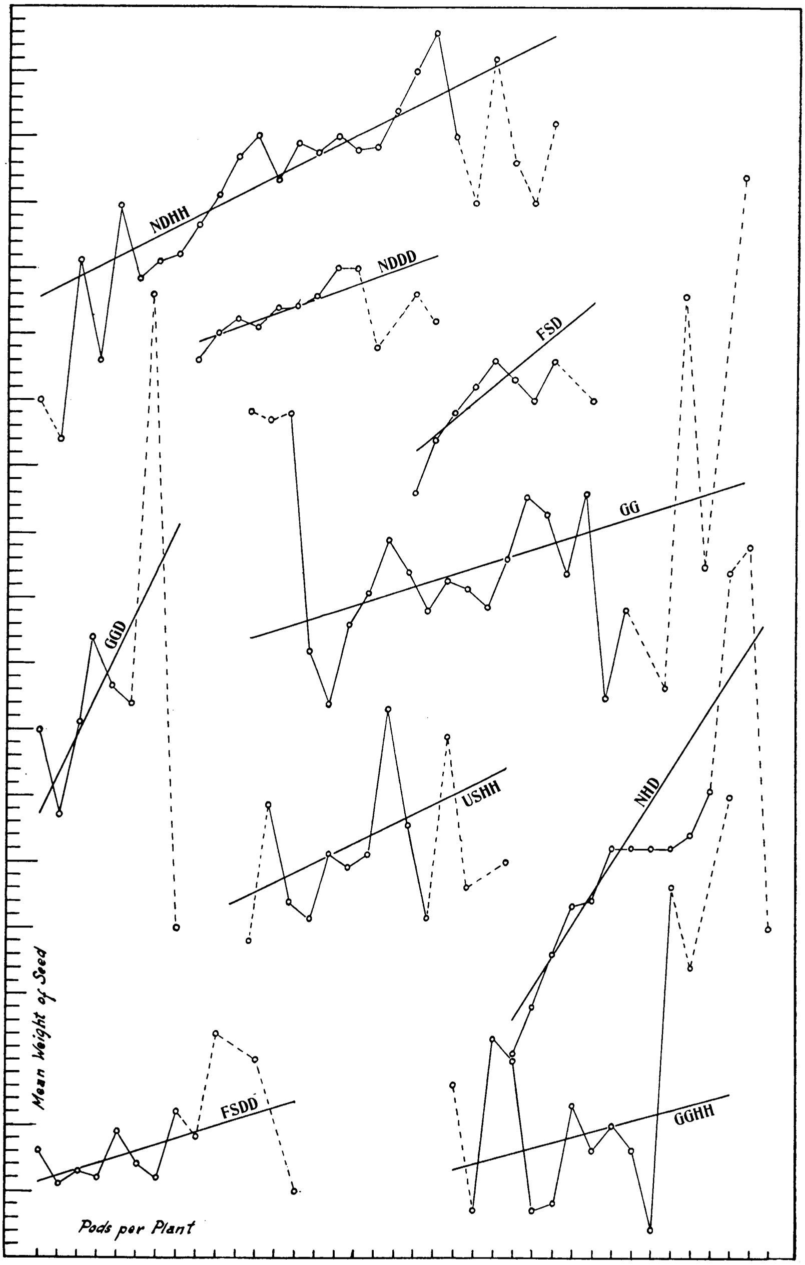

FIG. 2. Regression of seed weight on number of pods per plant. See explanation of FIG. 1.

given number of pods is small, this weighting will, I believe, tend to result in abnormal irregularity of the means of arrays. The biological reason for this condition I hope to discuss later.

Notwithstanding the conspicuous irregularity of the means, the number of regression diagrams in the two figures indicate that, taken by and large, a straight line represents the change in mean seed weight associated with variation in the number of pods on the plant as well as any other single equation would do.

It is quite idle to apply mathematical tests for goodness of fit in these series, for these involve the calculation of a measure of interdependence which is greatly influenced by the special difficulties which are met in graphical tests for linearity.

Thus, notwithstanding difficulties inherent in the materials the correlation coefficient seems the best numerical expression of the degree of interdependence between the variables.

All of the 27 values are positive. Numerically they are of a low

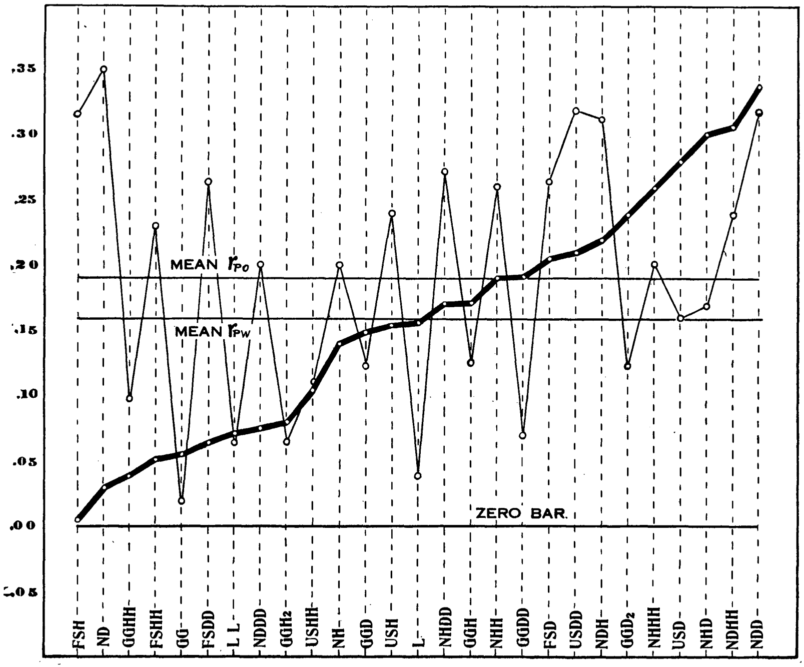

FIG. 3. Comparison of correlations between number of pods per plant and seed weight with that between number of pods per plant and number of ovules per pod in 27 cultures of *Phaseolus*.

order, ranging from +.005 to +.339 with the average value +.159. With two or three exceptions only, the correlation coefficients may be considered statistically significant in comparison with their probable errors.

As a basis of comparison there are available from an earlier paper* the constants showing the relationship between the number of ovules and seeds per pod and the number of pods per plant in these same series.

The results are exhibited graphically in FIGS. 3 and 4. In these the circles on the ordinates joined by the heavy lines show on the scale to the left the values of the correlations for number of pods per plant and seed weight arranged in the order of their magnitude. The circles connected by the narrow lines show on the same scale the magnitude of the correlations for ovules and seeds respectively.

The bars indicating the averages show that the mean correlation for number of pods per plant and number of ovules per plant is numerically higher than that for number of pods per plant and seed weight. The mean correlation for number of pods per plant and seeds per pod is lower than that for pods per plant and seed weight.

The magnitude of the differences is not, however, very large. The actual averages are:†

For pods per plant and ovules per pod,

$$r = .1924 \pm .0124.$$

For pods per plant and seeds per pod,

$$r = .1327 \pm .0118.$$

For pods per plant and seed weight,

$$\bar{r} = .1592 \pm .0119.$$

The difference between the mean value of the correlation for pods and ovules and pods and seed weight is therefore

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* Harris, J. Arthur. On the correlation between somatic characters and fertility. II. Illustrations from *Phaseolus vulgaris*. Amer. Jour. Bot. 1: 398–411. 1914.

† The mean values of the correlations for pods and ovules and pods and seeds given here differ slightly but insignificantly from those published elsewhere, because only 27 of the 32 series are used here.

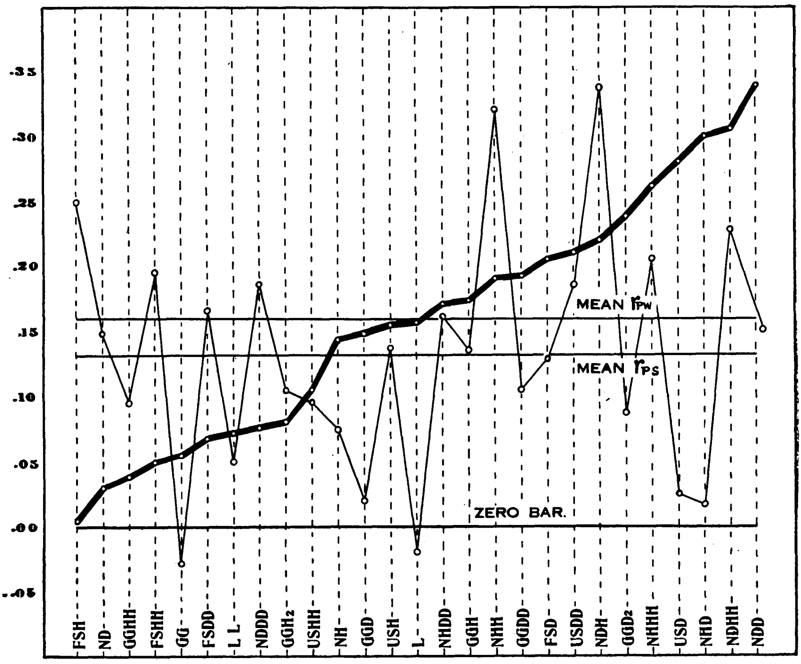

FIG. 4. Comparison of correlations between number of pods per plant and seed weight with that between number of pods per plant and number of seeds, matured per pod in 27 cultures of *Phaseolus*.

$$(.1592 - .1924) \pm \sqrt{(.0119)^2 + (.0124)^2} = - .0332 \pm .0172,$$

while that for pods and seeds and pods and weight is

$$(.1592 - .1327) \pm \sqrt{(.0119)^2 + (.0118)^2} = .0265 \pm .0168.$$

Differences in correlations of the order of .03 can ordinarily be given little weight. In the present instance neither of the differences is quite twice as large as its probable error. They cannot therefore be asserted to represent real physiological differences in the closeness of interdependence of the magnitudes of the three variables under consideration.

Not only are the means of the three correlations essentially the same, but the variability of the three sets of constants is practically identical. The values are:

For pods and ovules per pod, $\sigma_r = .0953 \pm .0087$.

For pods and seeds per pod, $\sigma_r = .0906 \pm .0083$.

For pods and seed weight, $\sigma_r = .0916 \pm .0084$.

The differences in the variabilities of the three sets of correlations are therefore:

For pods and ovules and pods and seeds, .0047 ± .0117.

For pods and ovules and pods and weight, .0037 ± .0118.

For pods and seeds and pods and weight, .0010 ± .0118.

All of these differences are only a fraction of their probable errors.

It is quite clear from the irregularity with which the values of the correlations for pods and ovules and for pods and seeds are scattered about the line showing the distribution of the correlations for number of pods per plant and seed weight, that there is very little if any interdependence between these three correlations.

IV. RECAPITULATION

This paper, which is one of a series dealing with the physiology of seed production, presents constants showing the degree of correlation between the weight attained by the individual seed and the number of pods per plant.

The correlations are positive throughout the twenty-seven series for which data are available, but are of a low order of magnitude and highly variable. They range from +.005 to +.339, with a mean of +.159 ± .012 and an absolute variability of .092 ± .008.

In both average magnitude and variability the correlations for seed weight and number of pods per plant are in excellent agreement with those for number of ovules per pod and number of pods per plant and with the correlation for number of seeds per pod and number of pods per plant.

The average value of the correlation for pods and weight is lower than that for pods per plant and ovules per pod and higher than that for pods per plant and seeds per pod, but both of these differences are low, and may not be significant in comparison with their probable errors.

These studies will be continued.

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